IN THE UNITED STATES DISTRICT COURT

FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex rel, W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA, et al.	)	
Plaintiffs,	)	
vs.	)	No. 05-CV-329-GKF-PJC
TYSON FOODS, INC., et al.,	)	
Defendants.	)	

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TRANSCRIPT OF NONJURY TRIAL PROCEEDINGS

JANUARY 25, 2010

BEFORE GREGORY K. FRIZZELL, U.S. DISTRICT JUDGE

REPORTED BY: *BRIAN P. NEIL, CSR-RPR, RMR, CRR*
United States Court Reporter

A P P E A R A N C E S

For the Plaintiffs:

MR. W.A. DREW EDMONDSON
MS. KELLY FOSTER
Office of Attorney General
State of Oklahoma
313 N.E. 21st St.
Oklahoma City, OK 73105

MR. DAVID RIGGS
MR. DAVID P. PAGE
MR. RICHARD T. GARREN
Riggs Abney Neal
Turpen Orbison & Lewis
502 W. 6th Street
Tulsa, OK 74119

MR. ROBERT A. NANCE
MS. KELLY FOSTER
Riggs Abney Neal
Turen Orbison & Lewis
5801 Broadway
Oklahoma City, OK 73118

MR. LOUIS W. BULLOCK
MR. ROBERT BLAKEMORE
Bullock Bullock &
Blakemore
110 W. 7th St.
Suite 770
Tulsa, OK 74119

MR. FREDERICK C. BAKER
MS. ELIZABETH CLAIRE XIDIS
MS. INGRID L. MOLL
Motley Rice LLC
28 Bridgeside
P.O. Box 1792
Mount Pleasant, SC 29465

A P P E A R A N C E S (Cont.)

For Tyson Foods:	MR. ROBERT W. GEORGE Tyson Foods, Inc. 2210 West Oaklawn Drive Springdale, AR 72701
	MR. FRANK R. VOLPE MR. MARK D. HOPSON MR. THOMAS C. GREEN MR. JAY THOMAS JORGENSEN MR. GORDON D. TODD ERIC J. IVES CARA R. VIGLUCCI LOPEZ Sidley Austin LLP 1501 K St. NW Washington, DC 20005
	MR. PATRICK MICHAEL RYAN Ryan Whaley Coldiron and Shandy PC 119 N. Robinson, Rm 900 Oklahoma City, OK 73102
For Cargill:	MR. JOHN H. TUCKER MS. THERESA HILL Rhodes Hieronymus Jones Tucker & Gable 100 W. 5th St., Ste 400 Tulsa, OK 74103
	MR. DELMAR R. EHRICH MS. KRISANN KLEIBACKER LEE Faerge & Benson 90 S. 7th St., Ste 2200 Minnaepolis, MN 55402
For Simmons Foods:	MR. JOHN R. ELROD MS. VICKI BRONSON Conner & Winters 211 E. Dickson St. Fayetteville, AR 72701

A P P E A R A N C E S (Cont.)

For Peterson Farms:	MR. A. SCOTT MCDANIEL MR. PHILIP HIXON MS. NICOLE LONGWELL McDaniel Hixon Longwell & Acord PLLC 320 S. Boston, Ste 700 Tulsa, OK 74103
For George's:	MR. GARY V. WEEKS MR. WOODY BASSETT MR. VINCENT O. CHADICK MS. K.C. TUCKER Bassett Law Firm P.O. Box 3618 Fayetteville, AR 72702
For Cal-Maine:	MR. ROBERT SANDERS Young Williams P.A. P.O. Box 23059 Jackson, MS 39225
	MR. ROBERT P. REDEMANN Perrine McGivern Redemann Reid Berry & Taylor PLLC P.O. Box 1710 Tulsa, OK 74101

I N D E X

Monday, January 25, 2010

* * * * *

THE COURT: Rebuttal.

MR. PAGE: Yes, Your Honor. The state would call Dr. Engel.

BERNARD ENGEL, PH.D.,

after having been first duly sworn, says in reply to the questions propounded as follows, to-wit:

THE COURT: Doctor, could you once again state your name for the record, please?

THE WITNESS: Sure. Bernard Engel.

THE COURT: Mr. Page.

MR. PAGE: Thank you, Your Honor. Good morning.

THE COURT: Good morning.

DIRECT EXAMINATION

BY MR. PAGE:

Q. Good morning, Dr. Engel.

A. Good morning.

Q. Dr. Engel, in preparation for your testimony today, have you reviewed and read Dr. Bierman's testimony in this case?

A. Yes.

Q. Okay, sir. Today I'd like to -- this morning I'd like to review with you some of the testimony that

Dr. Bierman gave in this case. The first area I'd like to talk to you about is Dr. Bierman's testimony concerning the omitted HRUs that were part of your modeling effort.

MR. PAGE: Can we have testimony slide or Demonstrative 420, please?

Q. *(BY MR. PAGE)* And in front of you, Dr. Engel, there's a set of all of these slides. So you might want to look at the first one.

(Discussion held off the record)

Q. *(BY MR. PAGE)* Dr. Engel, I want to read to you some of Dr. Bierman's testimony in this case?

"ANSWER: [Engel] independently confirmed that his models give the same answer whether he includes the entire watershed or leaves half of it out.

"QUESTION: And what percentage of the total land area in the watershed did Dr. Engel omit from his report?

"ANSWER: Fifty-four percent."

Now, Dr. Engel, do you agree with Dr. Bierman's testimony?

A. No.

Q. What is it that you disagree with, sir?

A. Well, first, I did input all of the data for

all of the watersheds into the model. So all of the data representing all of the HRUs were inputted into the model and the model was run. During the calibration of the model, inadvertently there were a group of the data that were not calibrated because as the model was being calibrated it only looked at the first nine hydrologic response units or HRUs. These would be unique combinations of land use and management that were being be model by the GLEAMS model.

So these were inadvertently -- the ones beyond nine in these watersheds were inadvertently left out and were not calibrated. The data was there, they were there when the model was run subsequently, but those remaining HRUs were not calibrated during the phosphorus calibration process.

Q. But all of the data had been inputted; that is, for all 50 HRUs, had been inputted into the GLEAMS model?

A. Yes.

Q. But the omission occurred during the calibration process; is that correct?

A. Correct.

Q. Okay. Now, what was the result then, sir, of the omission of not calibrating all 50 of the HRUs,

even though all of the data from all 50 HRUs was put in the model?

A. So the result would have been a calibration of only 27 of the 50. Those would have -- as a result of not considering the remainder of the HRUs during that calibration would have calibrated incorrectly and there would have been some 23 HRUs. That data was not modified during calibration because the algorithm did not look at those for calibration purposes.

Q. Now, this omission of about 23 of the 50 HRUs of calibration, did this affect the modeling results?

A. Yes, it did.

Q. Okay. Now, sir, then do you agree with Dr. Bierman's characterization that you got approximately the same results even though you left out one-half of the HRUs?

A. I would disagree with that.

Q. And would you please explain that, sir?

A. Certainly. So when I did put the HRUs in and calibrate this again, the results did change, so the results were similar, they were not identical in this particular instance. Part of that was because during calibration we're trying to adjust the inputs to the model within a range so that they better match the observed data.

And if we start with values of these coefficients that are modified during calibration that are within reasonable ranges and are good estimates, changing the -- changing those during calibration may result in relatively small changes to the overall model output.

So in this particular instance, we had good data, I'm experienced with the model having worked with it some 23 years on more than 50 applications, and based on my experience, you know, we didn't adjust some of these parameters, coefficients, to a great extent during calibration. So results were somewhat similar but they certainly were different.

Q. Now, when you discovered this error of the missing HRUs during the calibration process, what did you do?

A. Well, so when I discovered that they were missing, I had to go back and recalibrate the model so that it included those missing 23 HRUs. So it used the same process as before, except that the missing 23 HRUs were now calibrated this time. And so by including those in the total calibration mix, it changed the way the 27 HRUs were also calibrated because of the additional information that was considered during the calibration.

Q. Now, when you completed that recalibration, did you create new coefficients for your routing or the in-stream part of your model?

A. Yes. And let me explain.

So the in-stream model that takes phosphorus from edges of fields and from wastewater-treatment plants and moves that downstream to the three gauging stations nearest Lake Tenkiller -- and those would be the stations near Tahlequah and the Illinois River, near Eldon on the Barren Fork and on Caney Creek -- so the routing equation uses GLEAMS outputs. So the phosphorus predicted by GLEAMS to reach the edge of the field, it uses that as one of the inputs and it uses wastewater-treatment plant as one of the inputs.

So when I had to recalibrate GLEAMS, that changed the GLEAMS phosphorus that was predicted and, so therefore, it was necessary for me to in that instance modify my routing model, modify those coefficients.

Q. Now, Dr. Engel, during Dr. Bierman's examination, Dr. Bierman suggested that you or methods; that is, the methodology that you employed for modeling in the IRW, allowed you to alter coefficients in your model so that there was nothing wrong when he altered the coefficients of your model

when he did his tests.

Could we -- would you please turn to Demonstrative 421, which is testimony slide No. 2, please?

Now, Dr. Engel, this is from Dr. Bierman's testimony: "The Court: And you believed you were free to alter the coefficients because that was part, in your view, of Dr. Engel's model because he felt free to alter the coefficients; is that a fair layman's observation?

"The Witness: It is, sir. We both calibrated the same model. He calibrated his and I calibrated his."

Now, Dr. Engel, using your methodology, were you free to alter your coefficients of the routing model?

A. No.

Q. Did you freely alter the coefficients of your routing model?

A. No. The only time that I had to change those was when I had to recalibrate my GLEAMS model because GLEAMS provided inputs into the routing model. If it had been not for that mistake, the routing model would have been calibrated once and only once.

Q. Okay. Now, you ended up in this case

calibrating the GLEAMS model twice, correct, because of the HRU problem?

A. Correct.

Q. Okay. And so then you recalibrated the routing model how many times?

A. So I had to recalibrate the model -- well, I calibrated the routing model once initially with the incorrect GLEAMS inputs. And so when I discovered and corrected the GLEAMS because of this HRU calibration mistake, since GLEAMS is an input into the calibration -- or into the routing model, I had to subsequently modify the routing coefficients in the routing model. So they were set once initially incorrectly and then they were set the second time with the corrected GLEAMS inputs.

Q. Okay. So once you finished recalibrating the GLEAMS model, what did you do?

A. Well, so when I -- once I had finished recalibrating the GLEAMS model, the results of the GLEAMS model became one of the inputs into the routing model, the wastewater treatment was the second of those inputs, and then I used a computer program to identify the routing model coefficients that uniquely described the Illinois River situation based on substantial observed phosphorus loads at the three

gauging stations nearest Lake Tenkiller and using the GLEAMS outputs of phosphorus in the wastewater treatment effluent discharge data.

Q. Now, Dr. Engel, I just want to make sure this is perfectly clear.

After you discovered the HRU mistake and you recalibrated the GLEAMS model and the routing model, did you ever recalibrate or in any way change the coefficients for the routing model for the rest of the work you did in this case?

A. No.

Q. Did you ever recalibrate or change the coefficients when you did your model predictions?

A. No. So once the model was calibrated the second time -- the routing model calibrated the second time, as you would do in hydrologic water quality modeling, the coefficients remained fixed. So following calibration, these remained fix for a validation period and would remain fixed for any subsequent modeling prediction. So one would not alter those because that would change reality and would represent a different set of conditions that didn't exist.

Q. And is that what you did, what you just described there, about after you calibrate to maintain

then the coefficients, is that standard practice in watershed modeling procedures?

A. Yes.

Q. Now, Dr. Engel, I want to turn now to Dr. Bierman's claim that you did not have specific numerical values for these routing model coefficients in your report.

Would you please turn with me, sir, to Demonstrative 422, which is testimony slide No. 3? Do you have that, sir?

A. Yes.

Q. Question to Dr. Bierman: "You recalibrated. So you changed the model, did you not?

"ANSWER: In my opinion, I didn't change the model; I recalibrated the model.

"QUESTION: When you recalibrated the model, you changed the routing coefficients, at least some of them, for that model, did you not?

"ANSWER: I changed the coefficients, but in my opinion, that's not changing the model. Because in Dr. Engel's expert report on page D-21, he presents what he represents as his routing model. The routing model, as represented in his expert report, it doesn't have specific numerical values attached to the coefficients A, B, C, or P accumulation.

"QUESTION: So it's your testimony, sir, that Dr. Engel -- if you changed the coefficients in Dr. Engel's routing model, it (doesn't) change the model?

"ANSWER: It (doesn't) change the model; it changes the site-specific application of the model."

Now, Dr. Engel, is Dr. Bierman being truthful when he testified that your expert report does not have specific numerical values attached to the coefficients in your routing model?

MR. GEORGE: Objection, Your Honor; mischaracterizes the testimony that's actually on slide, which is referencing a specific part of the expert report on page D-21.

THE COURT: Rephrase.

Q. *(BY MR. PAGE)* Does Dr. Bierman's statement specifically truthfully characterize your expert report concerning the specificity of routing model coefficients?

MR. GEORGE: Same objection, Your Honor. The question as framed by the testimony he's rebutting is with reference to page D-21.

THE COURT: Sustained. Rephrase.

Q. *(BY MR. PAGE)* Dr. Engel, does your expert report actually provide the coefficients?

A. Yes, it does.

Q. Where? You have a copy of your expert report in front of you, sir.

A. If I could look at that, I can locate them. As I recall, they are on the subsequent page that follows D-21 where the equation is presented.

Q. So where in your expert report should we look, sir?

A. So it looks like page D-22 in the original report, table 7, provides these coefficients. So table 7 is labeled "coefficients for P load routing models." Some of these coefficients were subsequently modified, as I described earlier, as a result of the errata report. And so these are provided in the errata report --

Q. Is that also there in front of you, sir?

A. Yes, it is. And I'm thumbing through the pages here. Just a moment.

Looks like in the errata, those are in -- on page 45, again table 7, with the same name so they would appear there. So these would be the corrected and final routing equations -- or routing equation coefficients.

Q. So on the page following the page referenced in Dr. Bierman's testimony, you provided the specific

numerical values for your routing model, did you not?

A. Yes.

Q. And those values were modified because you found the HRU error, did you not?

MR. GEORGE: Objection; leading.

THE COURT: Overruled. We've already been over it. Go ahead.

MR. PAGE: Thank you, Your Honor. I'll just proceed then.

THE COURT: All right.

Q. *(BY MR. PAGE)* Dr. Engel, after you made the errata and changed these coefficients, did you ever modify these coefficients for your future work?

A. No, I did not.

Q. Okay. Next, Dr. Engel, I want to ask you about Dr. Bierman's opinion concerning his claim that your routing model is not really a water quality model.

Would you turn with me to Demonstrative 423, which is testimony slide No. 4? Do you have that, Dr. Engel?

A. Yes, I do.

Q. "QUESTION: You mentioned Dr. Engel's routing model. Is his routing model really a model, as you would use that term?

"ANSWER: I wouldn't call it a model. I would call it an empirical equation."

Do you agree with that opinion expressed by Dr. Bierman?

A. No.

Q. Would you please explain why you disagree with Dr. Bierman's opinion?

A. Certainly. So all models are made up of equations so even models like GLEAMS, SWAT, CE-QUAL-W2 that Dr. Wells uses has a series of equations in it. So models are made up of equations and really he's making a distinction here where there's not a difference to be made.

So this would be somewhat analogous to saying that, you know, the Dalmatian that I have is not a dog because it's a pet so it's both. So the distinction here is really not an appropriate distinction.

I guess expanding a little further on this, he's also talking about, you know, this being an empirical equation, you know, kind of the gold standard with engineers and scientists when there's observed data, and we can develop empirical equations that use that observed site-specific data that's preferred and we create an equation that does that.

So the routing model is certainly a model.

In trying to drawing a distinction that it's not a model because it's an equation, that doesn't make a lot of sense.

Q. Now, you mentioned that this is a site-specific routing model. What do you mean by that?

A. Well, because -- because I had the opportunity to use substantial observed phosphorus concentrations and flows and from that compute loads and develop a regression equation, regression model that linked phosphorus inputs into the stream from the GLEAMS model and from wastewater-treatment plants and connect that to the observed phosphorus loads, I was able to take advantage of this substantial data that existed within the Illinois River Watershed to develop a site-specific empirical routing model in this instance.

Q. Now, the routing model covers the phosphorus fate and transport from where to where?

A. From several places. So first, starting with wastewater treatment, so the wastewater treatment discharges into the streams so that would be one location.

The second would be from GLEAMS from the GLEAMS edge-of-field. So that's input into the

routing model. And the routing model then takes care of the fate and transport of the phosphorus, whether it be from wastewater treatment or from the GLEAMS model at the edges of these fields, and transports that taking into account all of the processes along the way. It does that implicitly. So it doesn't describe each one of those in detail, it describes those based on the observed data here in the Illinois River Watershed.

Ultimately, that phosphorus is delivered to the gauging stations near Lake Tenkiller so it tells how much and at what time.

Q. And those three gauging stations are which?

A. So, again, those would be the gauging station at Tahlequah on the Illinois River, Barren Fork near Eldon, and Caney Creek. So these are the three gauging stations closest to the lake.

Q. Now, what question were you trying to answer when you evaluated the fate and transport of phosphorus from wastewater-treatment plant and GLEAMS to these gauging stations?

A. So the question that was being answered at that stage was how much phosphorus reaches the gauging stations that I just talked about and when does it get there? So the interest was really in the magnitude

and timing of this, and in this particular instance the processes along the way and attribution of the responsibility of various processes in that fate and transport wasn't important. I just cared that the phosphorus got to the gauging stations, the amount, and the timing.

Q. So due to this question that you were focusing on, did that influence the decision as to whether or not you used the empirical routing model versus a mechanistic model?

A. Yes, it did. So because I didn't need to account and explicitly describe the uptake of phosphorus by aquatic organisms along the way, I could use this empirical equation based on observed data that described the timing and amounts of phosphorus reaching these gauging stations. So it wasn't necessary to describe explicitly these other processes.

Q. Okay. Now, Dr. Engel, I want to change subjects on you just a little bit again. I want to discuss with you Dr. Bierman's opinion that he simply recalibrated your routing model rather than changed your routing model.

If you would turn with me, sir, to Demonstrative 424, which is testimony slide No. 5,

sir.

"QUESTION: Doctor, after these loads were increased and the model was rerun, did you compare the results to the results of Dr. Engel?"

"Yes, I did the same thing here. I -- with my loads, I attempted to recalibrate Dr. Engel's routing model."

"And how did these loads compare?"

"The -- wastewater-treatment plant load was -- the load that I put in was, I think, 345 times the load that Dr. Engel put into the model. The nonpoint source load was 15 times higher than his nonpoint source load."

"And how did the results of the test compare, observed versus predicted, with Dr. Engel's?

"ANSWER: I was able to recalibrate Dr. Engel's routing model for both of these cases, and achieved R values that were equal to or better than his."

Now, Dr. Engel, do you agree with Dr. Bierman's testimony that he simply recalibrated your routing model rather than change it?

A. No. I disagree with his statement.

Q. And why do you disagree, sir?

A. Well, by greatly altering the inputs into the

routing model and then changing the coefficients, that didn't reflect reality. So if in reality point sources had increased 345 times, one would certainly expect far more phosphorus to be reaching the gauging stations.

Q. Well, then would it be reasonable then, if that was the case, to use the observed loads with 1/345th of the phosphorus being inputted into the IRW?

A. So this situation would not make sense. Because, as I said, with 345 times more phosphorus coming from this source, there would certainly be a change in the observed phosphorus loads. So in order to create a relationship among these, we have to have, you know, some ability to know that these are actual observed loads of phosphorus for the conditions under which we're developing the equation. That was not the case in this instance.

Q. Are you familiar with the term "boundary conditions" in the modeling jargon?

A. Yes.

Q. Does that -- does that concept apply to this circumstance?

A. Yes, it would. And let me explain why that would be the case.

So the other thing to note here is that Dr. Bierman uncoupled my GLEAMS model from the routing model, and so what he did is essentially violate then this boundary condition that was in place. So in altering the nonpoint-source pollution load some 345 -- or excuse me -- some 15 times, he didn't rerun the GLEAMS model, you know.

He would have had a very difficult time getting the GLEAMS model to predict this much additional phosphorus. I think you probably have to have rainfalls of Biblical proportions to do what he did here by altering the nonpoint-source inputs.

So by uncoupling and making this unrealistic going into the model -- into the routing model we no longer have reality. We have a case that certainly doesn't represent the Illinois River Watershed. It probably is a case that represents no place.

Q. Dr. Engel, in your opinion, would a scientist modeler ever unlink a model in the way Dr. Bierman employed in this case and attempt to calibrate the model using fictitious information?

A. No. I can't imagine that a scientist modeler would do that.

Q. Did Dr. Bierman calibrate the model in the same way you did?

A. No.

Q. How so?

A. I guess on several fronts. So first, as I talked about, the observed data really no longer matched the expectations for what the inputs were going into this.

Secondly, he had to alter the coefficients to the routing model in ways that didn't make sense. So with these greatly increased phosphorus loads, in order to make small amounts relative to the inputs continue to come out at Barren Fork, Caney Creek, and Tahlequah, it was necessary to make a substantial amount of phosphorus essentially disappear. There was a term in the model that allowed that phosphorus to disappear, if you will, by forcing it to be accumulated in the stream system.

So by making these realistic -- or excuse me -- by making these unrealistic coefficients and forcing things to be unrealistic, he was able to produce similar results but for a situation that no longer represents the Illinois River Watershed.

Q. Now, when Dr. Bierman changed these inputs, did he actually use your model; that is, run your model, to make a comparison of the outputs of these hypotheticals to your model outputs?

A. No. And I guess let me explain a couple things again.

So, again, first, he never ran the GLEAMS model to produce the -- to produce the increased nonpoint source loads. And secondly, he didn't use my model with my coefficients to route his changed inputs to the routing model. He altered the routing model coefficients.

Q. And for the other example that we've been talking about, the 345 times increase of wastewater-treatment plant, did Dr. Bierman have any data discharge monitoring reports of any type that would suggest that such a discharge was occurring in the IRW?

A. No.

Q. And when he did put that type of a wastewater-treatment plant input into the routing model, did he change the routing model before he got his results?

A. Yes. He altered the routing model, he changed the coefficients so that he could lose phosphorus and force that phosphorus to accumulate in the stream network, and in other instances he had to use coefficients that didn't make sense physically.

Q. Okay. Now, Dr. Engel, I'd like you to look

now at Demonstrative 425. It's testimony slide 6. Do you have that, sir?

A. Yes.

Q. "QUESTION: Isn't it true, sir, that when you changed these coefficients, you created a different routing model?

"ANSWER: I disagree with that opinion. It's the same model, but the -- it's a different calibration of the same model. I guess we can get hung up on semantics here. So the terms -- I will concede that my coefficients are different. I should also point out that Dr. Engel during his deposition stated . . . these coefficients have no physical meaning and there are no constraints on what values they could take when he calibrated the model."

Now, Dr. Engel, do you agree with Dr. Bierman's opinion that changing the coefficients did not change your model?

A. No. It changed the model.

Q. How so?

A. Well, as the coefficients were changed, it created a model that no longer represented the Illinois River Watershed. It represented some made-up location, probably a location that doesn't exist.

Q. Now, do you agree with Dr. Bierman's

characterization in this testimony "that these coefficients have no physical meaning and there are no constraints on what values they could take"?

A. No. I recall, at least on several occasions, in my deposition that I did talk about, you know, physical meaning tied to these, and also I did talk about potential ranges of constraints. Certainly one would have to think through logically what values these might take on and make sense.

Q. Well, can you give us an example of the coefficients having a physical restraint in your model?

A. Yes, certainly. So one of the coefficients, A, in the routing model describes the case when there's no flow. So if there's no flow reaching one of the gauging stations, physics and logic would dictate that the phosphorus load would need to be awfully close, if not zero, so it should be very close to zero. And so the A coefficient in that particular case should be very small, should be near zero, if this routing model is to make sense.

Q. Okay. And did Dr. Bierman's circumstances, when he changed the routing model and changed the coefficients, did he change the A coefficient?

A. There were several instances in which he did

change the A coefficient. As I recall in one of those instances, it took on a value of 140 kilograms per day and I believe in another case maybe 90 kilograms per day.

That would indicate, if one believed that made-up model, that phosphorus was being delivered when there was no flow on the -- of the magnitude of 140 kilograms per day. So physics and logic again would dictate that that simply doesn't make sense.

Q. Are there other coefficients that also represent physical processes -- that is, coefficients that are in the routing model you have -- represent other physical processes and are constrained in your routing model?

A. So there would be coefficients B and C that describe the rates of transport of phosphorus through the -- through the stream system so those would describe rates. And if those are modified in a way that they no longer make sense in this particular instance, those would be the mechanisms by which one could potentially make phosphorus disappear, if you will, or force that phosphorus to stay in the stream and continue to accumulate to values that are unrealistic in this particular case.

Q. Now, Doctor, I want to speak with you now

about Dr. Bierman's testimony that no matter what P inputs are used in your model; that is, phosphorus inputs are used in your model, the model always produces the same results and the use of his sensitivity tests, that he called them, to achieve that opinion.

Would you turn with me, sir, to Demonstrative 426, which is testimony slide No. 7?

"QUESTION: What is it about Dr. Engel's routing model that allows it to consistently produce similar results, regardless of the changes in the inputs?

"ANSWER: Well, there are two things. It's an empirical statistical equation. It does not explicitly represent any of the physical, chemical and biological processes that actually influence the transport, fate, delivery, the journey, the pathway of (the) phosphorus through the Illinois River stream and network. Another reason is that in each case when Dr. Engel conducted his calibration and purported validation, he compared what he called predicted loads to observed loads. What Dr. Engel did (in) his predicted loads on the vertical axis were not independently determined because he also used measured USGS flows at the bottom of the watershed to determine

the predicted loads on the Y axis."

Now, Dr. Engel, do you agree with Dr. Bierman that you get the same results from your model regardless of the phosphorus inputs?

MR. GEORGE: Objection, Your Honor. That's the -- that's not the testimony that's cited in the answer. The question mischaracterizes the testimony.

MR. PAGE: Your Honor, the question clearly implies that and clearly that was part of his testimony in this case.

MR. GEORGE: Your Honor, I apologize. With all due respect, the witness is here to rebut the testimony of Dr. Bierman, not the question. So the question is what it is and Dr. Bierman's answer is on the screen. If he disagrees with it, he's entitled to rebut it but --

THE COURT: Rephrase, please.

Q. *(BY MR. PAGE)* Do you always get the same results no matter what phosphorus is inputted into the river because of the fact that you have an empirical equation that supports your routing model?

A. No.

Q. Okay. Would you explain to the court why that is?

A. Certainly. So the model has coefficients that describe the fate and transport of phosphorus through the stream system. So as one changes phosphorus inputs, the predicted amounts of phosphorus change in a corresponding manner. And, in fact, I did some -- some experimental work and modified inputs into the routing model equation and I certainly get different results.

Q. Okay. Did you actually take the four so-called sensitivity tests that Dr. Bierman performed and run them -- those inputs with your model to see if you get the same results as the inputs from GLEAMS and wastewater-treatment plant that you used?

A. Yes, I did. So what I did was to take his four scenarios -- so the increased nonpoint-source phosphorus, the increased wastewater-treatment plant phosphorus, the reversed inputs reversed from what I had used, and I believe he also had a scenario that he called the S&P index using the S&P index to represent phosphorus -- I used my model, my coefficients, and obtained routing model results for those four scenarios.

Q. Okay. Now, in order to understand this, I want to ask you just a couple of background questions.

First, I want to start with Demonstrative

No. 392. Do you have that in front of you, sir? And I want to use this to then go through each of these four tests that you just testified to, sir.

Now, what is shown on Demonstrative 392?

A. So 392 shows the routing model equation, and the routing model equation predicts phosphorus load delivered to each of one of the three gauging stations that we've been talking each day.

Q. And these gauging stations are where again?

A. So they are nearest the lake, so they're at Tahlequah, Barren Fork near Eldon, and Caney Creek. So those would be the three locations.

Q. Thank you.

A. So this model was applied at each of these three locations. The model calculates phosphorus load each day and phosphorus load each day is calculated as follows. So phosphorus load equals A, a coefficient. So this would describe, as we talked about earlier, the amount of phosphorus one would expect to reach that gauge when there's no flow. So that should be about zero in most instances.

And then it says that a coefficient B times flow, represented by Q here in this equation, times phosphorus accumulation in the stream network. So that describes transport of phosphorus from

edge-of-field and wastewater treatment discharges based on how much flow, how much phosphorus is in the stream network.

And then the last term in the model is a coefficient C multiplied by flow squared, so the concept here being that on days in which there are very high flows we have substantially more phosphorus being transported, times again phosphorus accumulation.

Q. Okay. And this is the equation that you used for all of your modeling processes; correct?

A. Correct.

Q. Okay. Now, I want you to look with us, sir, on slide Demonstrative 393. Now, did you prepare this slide, sir?

A. Yes.

Q. Okay. And what does this show?

A. So this slide -- I picked out the Barren Fork routing models for my model, so that's going to be described on the top of the slide, and for Dr. Bierman's model when he increased the nonpoint-source phosphorus inputs.

I picked Barren Fork in particular because in Dr. Bierman's analysis he modified the phosphorus inputs for nonpoint source by 1,000 times. And,

again, I would just remind you that he didn't run the GLEAMS model to do that; he simply took my GLEAMS model predictions of nonpoint source and multiplied those by one thousand.

Q. Now, Dr. Bierman testified that he increased nonpoint source 15 times. What do you mean then the Barren Fork inputs increased by as much as a thousand times?

A. So he didn't alter the nonpoint source inputs to a very large degree for the Illinois River at Tahlequah or for Caney Creek. So the majority of that nonpoint source change; in fact, it was again an increase of one thousand times, was done on the Barren Fork.

Q. Now, would you please explain then how a layman, such as myself, can see the differences between your model and what Dr. Bierman's model was for increased nonpoint-source phosphorus?

A. Certainly. So, again, at the top is my model for the Barren Fork. It says that phosphorus load is equal to the equation that we see. And then we see Dr. Bierman's equation underneath this.

Let me point out the differences. It looks like I bolded the B coefficient, the C coefficient, and the starting phosphorus accumulation. So these

were the -- in this instance, these were the coefficients that were altered.

So if we look at the B coefficient in my model, this is the 4.7 times 10 to the minus 13, a small number. And in Dr. Bierman's equation, he used 4.0 times 10 to the minus 13. So, again, this describes how quickly phosphorus is going to be moving through the -- through this Barren Fork stream system.

And then the C equation, my value is 1.75 times 10 to the minus 9, while Dr. Bierman used 1.2 times 10 to the minus 12. This difference would be approximately three orders of magnitude or nearly a thousand percent.

So this was a pretty substantial change during high rates or higher rates of flow to slow down and force phosphorus, if you will, again to disappear, or in this particular case end up being accumulated in this -- in a term in the model that accounted for the accumulating phosphorus in the stream.

Q. Now, I just want to make sure the record is clear that these coefficients that are shown under Dr. Engel's model in Demonstrative 393 that you just described, those are all found on page 45 of your errata; correct?

A. Yes.

Q. Okay. Now, how did you determine the coefficients that Dr. Bierman used when he altered the nonpoint source inputs?

A. So the routing model was implemented in an Excel spreadsheet, and so I looked in the corresponding Excel spreadsheet for each of the four scenarios that Dr. Bierman ran.

Q. Okay. Would you please, sir, look at Demonstrative 395? Did you create this demonstrative, sir?

A. Yes.

Q. Okay. Would you please explain what it shows?

A. So this is a small portion of an Excel spreadsheet in which the routing models were implemented.

Q. Okay. Implemented by who, sir?

A. So this routing spreadsheet is Dr. Bierman's. We can see at the top the name of the file, here at the very top of this. Let me focus in particular on this Barren Fork portion of this.

So if we look in columns O and P near the top here, in the O column we see A, B, C, so those are the A, B, C coefficients. And then in the P column, we see the corresponding values that Dr. Bierman used for

these A, B, and C values.

Q. So those are the values that you showed on Demonstrative 393 that you just testified to?

A. That's correct.

Q. Okay, sir. Now, when you did your analysis and review of this Excel spreadsheet from Dr. Bierman's considered -- I assume this came from his considered materials?

A. Correct.

Q. Okay, sir. When you did this review, were you able to determine how Dr. Bierman was able to obtain similar predictions of loading to Lake Tenkiller by using this model?

A. Yes, I was able to determine that.

Q. And how did he do that?

A. So again, first, he altered coefficients B and C. He also did alter slightly the starting phosphorus accumulation found in column M. Then if we look at how the routing model worked, we can look in column M and see how phosphorus accumulates.

So, again, in making phosphorus disappear so that it wasn't delivered to the gauging station at Barren Fork near Eldon, that phosphorus had to stay in the stream and so that was the phosphorus accumulation term. So if we were to look at the bottom of this

spreadsheet, we could see how much phosphorus accumulated.

Q. Well, did you make a demonstrative that shows the bottom of this spreadsheet, sir?

A. Yes, I did.

Q. Okay. Would you please look at Demonstrative 396, and would you please explain for the court what we're looking at here?

A. So now we've -- we've moved down some 3200, 3300 lines. We can see that over in the left-hand column here. Still column M is where we're accumulating phosphorus in Barren Fork. And so if we look here on December 31st, 2006, we'll see the amount of phosphorus that is now accumulated.

Q. And what column is that again, sir?

A. It's column M and it would be line 3291. So if you recall, when we started up at the top of the spreadsheet, we started with about 20,000 kilograms of phosphorus in the stream. By the time we get to 12/31/2006, Dr. Bierman's model has predicted nearly 589 million kilograms of phosphorus have now accumulated in the Barren Fork.

And to provide a little context, that represents about five percent of the phosphorus that's mined globally on an annual basis. So if this were a

realistic value of phosphorus being accumulated in just the Barren Fork stream, I would suspect we would see all kinds of mining companies wanting to come mine phosphorus from the Barren Fork

Q. Now, Dr. Engel, did you compare this 589 million kilograms of phosphorus that Dr. Bierman has in the Barren Fork to what your model predicted would be in the Barren Fork after this 1998 to 2006 time period passed?

A. I did. My recollection is that what I found with my model is about 171,000 kilograms, so certainly within a very, very reasonable range that one would expect. So even though we've had some dry years recently, that would force phosphorus to accumulate and so that's well within a bound that one might expect.

Q. Now, if, in fact, you add the nonpoint source loads that Dr. Bierman suggests but don't change the routing model, use your routing model with the coefficients you developed, do you get different modeling results?

A. They're very, very different results when one does that.

Q. Did you actually do any tests to support that conclusion?

A. I did.
Q. What did you do?
A. So what I did was to take my model with my coefficients and use Dr. Bierman's inputs to see what would happen.
Q. Okay. And what were the results you found when you ran Dr. Bierman's fictitious nonpoint source inputs but using your model?
A. So what I found was that the phosphorus delivered -- and, again, I looked at all of these but Barren Fork was the most altered of these. So using Barren Fork as an example again, at Barren Fork I found that there was a great deal of additional phosphorus being delivered. My recollection is that ranged from tens of millions of pounds per year to more than 250 million pounds a year of phosphorus being delivered to that location. So very, very different than the values I had obtained.
Q. Would you please look with me, sir, to Demonstrative 394? Do you have that, sir?
A. Yes.
Q. Dr. Engel, did you prepare this demonstrative?
A. Yes.
Q. What is shown on this demonstrative, sir?

A. So this demonstrative depicts the results for my model with -- with the phosphorus inputs that had been observed from the wastewater treatment and my GLEAMS-predicted, nonpoint-source phosphorus inputs. So those are going to be the results at the bottom.

Q. So at the bottom, these are your model results using your runs for the IRW in this case?

A. Yes. So I guess in this particular instance, I've combined the Barren Fork, Caney Creek, and the Illinois River at Tahlequah. So these represent the loads to Lake Tenkiller.

Q. Okay, sir. And explain to the court the information that's on the bottom graph; that is, on the X and Y axis.

A. Certainly. So we have phosphorus loads here in pounds. And note that the scale here on the Y axis changes by 200,000 pounds, and then each of the red bars represent the phosphorus loads as predicted by my -- by my model to Lake Tenkiller for years 1998 through 2006.

So if we pick year 2004, for example, we see that a little more than one million pounds of phosphorus is predicted to be delivered to Lake Tenkiller.

Q. Okay. Now, what is shown on the top part of

this demonstrative, sir?

A. So on the top, I used my model, my coefficients for each of the three streams, so Barren Fork, Caney Creek, and the Illinois River to Tahlequah. So left that unchanged, put in Dr. Bierman's inflated nonpoint-source phosphorus in each of those cases, and then obtained modeled -- routed model results for each of the years as I had done for my model. So those are depicted here in the top here in the chart with the blue bars.

Q. And on this chart showing the model results using Dr. Bierman's inputs, is it on the same scale as your results at the bottom?

A. No. So let me point out the Y axis here. The scale increments are 50 million-pound increments. And, again, if we pick out year 2004 as an example, in this particular instance, the routing model predicts that there would be in excess of 250 million pounds of phosphorus delivered to Lake Tenkiller in 2004. And, again, recall my model with my wastewater treatment and my GLEAMS nonpoint source inputs predicts a little over a million pounds for that same year.

THE COURT: Which of Dr. Bierman's four fictitious scenarios are you using at the top?

THE WITNESS: This is the increased

nonpoint-source phosphorus load one.

THE COURT: All right.

THE WITNESS: So where he increased nonpoint source phosphorus loads by 15 times, I believe.

THE COURT: All right.

Q. *(BY MR. PAGE)* Okay. Now, did you also do this type of an analysis for Dr. Bierman's fictitious wastewater-treatment plant inputs?

A. Yes, I did.

Q. Okay. And what did you discover when you did or ran that analysis?

A. So, again, the wastewater-treatment plant inputs were inflated by 345 times, as I recall. So when I ran that analysis with my models with my coefficients, again, I found very substantial loads that varied quite substantially from the results that I had obtained.

Q. Okay. Before you actually ran his inputs in your model, did you look at his model where he modified those wastewater-treatment plant inputs to see if there's any differences between your model and his model?

A. I did look at that as well, yes.

Q. And what did you find?

(Discussion held off the record)

A. What I found was that for that instance he had also altered the routing model coefficients, and, in fact, in that instance again had to force values for the B and C coefficient to be small so that we could make phosphorus disappear again and accumulate in the stream. Again, the majority of the change was done on the Barren Fork so the majority of that phosphorus was accumulated in Barren Fork.

And the second thing that I noted in that instance was that he also had to greatly alter the A coefficient, the value that one would expect of phosphorus load on days in which there was no flow, and that took on a value, if I remember, of about 90 kilograms per day. So that would not make sense from a physical standpoint.

Q. *(BY MR. PAGE)* Now, in this Dr. Bierman scenario where he had the increased wastewater-treatment plant loads, how much phosphorus was accumulated in the Barren Fork?

A. In the Barren Fork again, it was in excess of 500 million kilograms over the nine-year period.

Q. And, again, that compares to what accumulation you had for your model?

A. In my model was about one hundred seventy,

one hundred seventy-one thousand kilograms.

Q. Okay. Now, sir, let's look at Demonstrative 390. Did you prepare this demonstrative, sir?

A. Yes.

Q. Okay. What is shown on Demonstrative 390?

A. So Demonstrative 390 are the results for the increased wastewater-treatment plant inputs that Dr. Bierman did. So let me start at the bottom again.

So at the bottom is my model as presented in my report, the results for it --

Q. These are the same modeling results that we had in Demonstrative 394?

A. The 394 -- yes, 394 was the previous one. So yes, those are the same modeling results presented in the previous demonstrative.

Q. Which are your modeling results?

A. Yes.

Q. And for each year, sir, what are the results that your model predicted?

A. So my model predicted results that ranged in -- let me just pick 2003 -- from a little less than 200,000 to something over 1.1 million in 2000. So they varied within that range.

Q. Okay. Now, sir, what is shown on the -- and what are the increments here that are shown on your --

A. So, again, on my model results in red at the bottom, the Y increment is 200,000 as it was in the prior demonstrative.

Q. Okay. Now, what is shown then on the top of Demonstrative 390?

A. So on the top, I took my model, left the coefficients the same, put in the increased wastewater-treatment plant phosphorus increases that Dr. Bierman had used, and then predicted the amount of phosphorus delivered to Lake Tenkiller.

Q. Okay. So how does this result where you add the 345 times more wastewater-treatment plant phosphorus to your model, how does that compare to your modeling results?

A. First, let me point out again that the Y axis here is quite different, so the Y axis increments are 50 million. So don't get confused maybe that the shapes look the same.

So, again, if we pick out a particular year, maybe in this case 2000, I predicted about 1.1 million pounds of phosphorus being delivered and Dr. Bierman predicted nearly -- well, with Dr. Bierman's wastewater treatment increases and my model, I predicted nearly 250 million pounds of phosphorus delivered in that instance.

Q. Is there any year for these modeling runs in which Dr. Bierman's -- we can use Dr. Bierman's inputs of 345 times the wastewater-treatment plant that it gets similar or the same results as your inputs using your model?

A. No. So even these low years in '98 or 2003, these are nearly ten million pounds in those particular years.

Q. Okay. Now, did you also -- there's two other tests that Dr. Bierman said sensitivity tests. There's one called the S&P hypothetical where he took what he claimed were values from the Standard and Poor's index and put it in.

Did you also test those inputs in the similar fashion that you just testified with regard to wastewater-treatment plant and nonpoint source inputs?

A. Yes, I did. I first looked to see if the coefficients for the routing model had been altered in those cases and they had. Then I returned those to the values that I had used and reran the routing models to see what the results would be.

Q. Okay. And what did you find when you used Dr. Bierman's S&P inputs, instead of your GLEAMS and wastewater-treatment plant inputs, but used your model to evaluate it?

A. So when I used my model with Dr. Bierman's S&P inputs, I got different results. So they were certainly more similar than the results we've been looking at. I can explain that.

So if one sums up the total phosphorus inputs represented by the S&P that Dr. Bierman used as phosphorus inputs to the routing model, those are of similar magnitude to my combined inputs of wastewater treatment and nonpoint-source phosphorus. There will be variability year to year in the results and there's fairly substantial variability day to day in results.

Q. Okay. So even though there was similar inputs, I guess, over the whole nine-year period; is that what your testimony is?

A. Yes. Over the nine-year period, if we sum those up, if we sum up Dr. Bierman's S&P inputs over the nine years, those are of similar magnitude, a little bit more, than my total phosphorus inputs.

Q. But even though they were similar, did your model predict different results using the different input data?

A. The model results were different.

Q. Okay. Would you please look with me, sir, to Demonstrative 417? What is shown on this demonstrative, sir?

A. This demonstrative shows modeling results for my model unchanged so with the original wastewater treatment and the original GLEAMS inputs; those are shown in red. And in blue is my model with my coefficients, but rather than wastewater treatment and rather than the GLEAMS nonpoint-source phosphorus inputs, those are replaced with Dr. Bierman's S&P inputs for that same period.

Q. So if you used the different inputs; that is, the S&P inputs suggested by Dr. Bierman, is there any year in which you get the same results as using your inputs using your model in both cases?

A. No. So we can -- we can clearly see that here in the bar chart.

Q. Now, did you actually compute what the average daily difference was between using your model but using Dr. Bierman's inputs versus your inputs from GLEAMS and actual wastewater-treatment plant discharge monitoring reports?

A. I did. And what I found was that the average daily difference in this case was 187 percent. Let me explain what that means.

So what that would indicate would be that if I predicted 100 for a particular day, on average Dr. Bierman's model predicted 287 or something on the

order of something down in the tens or twenties so fairly substantial differences. But if you aggregate those over a year, one gets similar results but the daily results are quite different.

Q. So even if you used similar data, like the S&P results, do you always get the same results with your model no matter what inputs are there?

A. No, you don't.

Q. Okay. Now, did you also do this analysis when Dr. Bierman -- I think it was his fourth of four sensitivity tests concerning the reverse; that is, I think he testified that he reversed day one and put that the last day and put the last day the first day and ran those in the model.

A. I investigated the coefficients and found they were altered and so then I reran that with my model, my coefficients.

Q. Okay. So in order to get similar results by reversing the data, what did Dr. Bierman have to do?

A. So, again, he altered the coefficients in that particular instance so those were modified versus what I had used in my model.

Q. Okay. Would you look with me, sir, to Demonstrative 416? Do you have that, sir?

A. Yes.

Q. Okay. Did you prepare this, sir?
A. Yes.
Q. What is shown on Demonstrative 416?
A. So this demonstrative has the results for the reversed input. So, again, in red are my model with my original inputs, my coefficients. In blue is my model, my original coefficients, but like Dr. Bierman did, I reversed the inputs. So I took the December 31st, 2006, phosphorus input and made that the January 1, 1998, input and continued that reversal process.
And so I then reran the routing model, my coefficients, phosphorus inputs reversed, and obtained the results that are shown in blue.
Q. So when you use your model, your routing model, with these different inputs, do you get the same results as you ran when you got your model?
A. No. Again, one can see that they do vary year by year and the magnitude of those differences varies over time as well.
Q. Did you also compute what the average daily difference was between Dr. Bierman's inputs using your model versus your inputs using your model?
A. I did. And in this instance, that daily difference was approximately 77 percent. So Dr. Bierman's model varied on any particular day by

about 77 percent on average versus what I predicted.

Q. So, Dr. Engel, do you agree with Dr. Bierman's testimony that no matter what P inputs are used in your model, the model always results in the same --

MR. GEORGE: Objection; mischaracterizes Dr. Bierman's testimony.

THE COURT: Overruled.

A. You certainly get different results as I've demonstrated with the testimony I've just given.

Q. *(BY MR. PAGE)* Does that make sense to you, sir?

A. Well, one would certainly expect different results if you put in different inputs.

Q. Now, I want to go back, sir, to testimony slide No. 7, which we've been talking through here about the results, and look at specifically on a couple of other points that was made by Dr. Bierman on that slide. And, again, that testimony slide No. 7, which is Demonstrative No. 426. Do you have that, sir?

A. I can see it on the screen here.

Q. Okay. Now, do you see where Dr. Bierman states that your model doesn't explicitly represent physical phosphorus processes in the IRW stream

network?

A. Yes.

Q. Do you agree with that testimony, sir?

A. Well, it doesn't explicitly represent those processes, but it's not necessary to explicitly represent those processes in order to have a model that's accurate and able to correctly characterize the fate and transport of phosphorus in the Illinois River Watershed.

Q. Okay. I also want to ask you about that second comment, and that is that Dr. Bierman states that the predicted loads were not independently determined.

Do you see that at the bottom of this testimony slide, sir?

A. Yes.

Q. Do you agree with Dr. Bierman's characterization?

A. No.

Q. Okay. Would you please explain to the court why you disagree with Dr. Bierman's characterization?

A. So what Dr. Bierman is saying here is that since flow was used in identifying the observed loads and flow is used in transporting phosphorus to that location, that no matter what you put in, you would

expect to get the same answer.

So I guess, first, you know, flow is the process that carries the phosphorus and so it makes sense that flow is in this. Secondly, if you do remove flow in both instances, you're left with concentration.

And so in this particular instance, no matter what you put in, you didn't get the same answer. So it's demonstrating that, you know, it's not flow that's driving this so this statement doesn't make sense.

Q. Does your model ignore everything that occurs from the edge of the fields or the wastewater-treatment plant discharge to the gauging stations?

A. No.

Q. And would you please briefly explain that, sir?

MR. GEORGE: I'm sorry, Your Honor, objection. I don't believe this is a topic that has been disclosed in the state filing for rebuttal testimony. If it is, I missed it. I apologize.

THE COURT: Mr. Page.

MR. PAGE: Yes, it is. I can go ahead and go to the slide, Your Honor, if that would -- I

was just trying to move things along. But I'll put the slide up. It's Demonstrative 427, Counsel.

THE COURT: Well, but that doesn't deal with the objection. He's saying the subject matter wasn't raised. Now, I recall us talking about this, but was it identified as part of the subject matter of the rebuttal?

MR. GEORGE: Your Honor, someone has pointed out to me that there is a topic that touches upon it. It's apparently topic 8 in the filing. So I withdraw my objection.

THE COURT: Okay. Thank you. I do remember us talking about it. Go ahead.

Q. *(BY MR. PAGE)* Maybe it would be cleaner if we looked at the demonstrative slide, sir, Demonstrative 427, testimony slide No. 8.

"QUESTION: Doctor, please explain the issue with respect to the routing model.

"ANSWER: So the routing model makes the connection between the loads he computed at the edges of (the) fields . . . and these three stations at the base of the watershed. And the issue there is that he ignores everything that happens in between the edges of these fields and these three stations. He does not explicitly represent any of the transport, fate or

delivery process in over 3,000 miles of watershed."

Now, do you agree with this testimony, sir?

A. No.

Q. Would you please explain?

A. Yes. So the model that I created is a model based on the observed data in the Illinois River Watershed. It takes inputs from edge-of-field from GLEAMS from wastewater-treatment plants and determines when and how much of that phosphorus gets delivered at the three gauging stations nearest the lake, so Barren Fork, Caney Creek, and Tahlequah on the Illinois.

In doing so, the model is representing the processes along the way. It may not do that explicitly, as is highlighted here in the slide, but within that model those processes are represented by the observed data so they are represented.

Q. So why did you choose a model that does not explicitly represent the different phosphorus processes from the edges of fields to the gauging stations near Lake Tenkiller?

A. So there were a couple of reasons. So, first, it wasn't necessary in this instance. So in this case, my goal was to identify the amount of phosphorus reaching the three gauging stations that I've mentioned and then be able to use that

information with predictions of future scenarios to understand what was going on and to use that information in allocating phosphorus to various sources.

To do that, it wasn't necessary to explicitly describe each and every process of that phosphorus along the way. I was able to use the substantial observed data from the Illinois River Watershed to create an empirical relationship that described that.

So further, if we had used an explicit mechanistic routing equation that did represent these processes, we would still have to calculate and identify coefficients. So those processes would have been identified, there would be coefficients that would modify the interactions among those, and those coefficients would initially have been set for other watersheds. So one maybe could have attempted to use those coefficients but probably would have had to calibrate in this instance as well.

I guess further in that calibration process, you have to decide the interactions then among these various fate and transport processes. For what I was doing, it wasn't necessary to worry about and to try to account for that detail in that complexity. In fact, that often introduces error.

So in my particular case, I was able to use the observed data, create an empirical relationship that did describe implicitly fate and transport processes, it took the phosphorus from the edge of the field, took phosphorus from the wastewater treatment, and determined when this showed up at the gauging stations and how much of it showed up. It just didn't describe every process along the way.

THE COURT: Let's take a break. We're here in this subject matter at the heart of this lawsuit in terms of causation relative to describing the process between the edge-of-field and these three gauging stations. I mean, this is the heart in terms of causation so we need to focus on this.

Let's take a recess.

(Short break)

THE COURT: Mr. Page.

MR. PAGE: Thank you, Your Honor.

THE COURT: Yes, sir.

Q. *(BY MR. PAGE)* Dr. Engel, before the break, we were talking about the empirical routing model that you employed. Now, this empirical model models phosphorus from where to where?

A. So it models the phosphorus as it reaches the edge of the field as predicted by the GLEAMS model so

from edge-of-field. The second place it picks up phosphorus is from the wastewater-treatment plants, the locations they discharge. So once that water now is in the channel stream network for a particular stream or river -- Barren Fork would be an example -- the model then routes that from edge-of-field from wastewater-treatment plant location until it would reach the gauging station near the lake; Barren Fork again an example.

Q. So the GLEAMS model represents the processes for runoff of the edge of the field; correct?

A. Yes.

Q. So it gets the phosphorus from the field to the edge of the field for runoff; correct?

A. Correct.

Q. And so the routing model we're talking about now is from the edge of the field or from the discharge pipe to the gauging stations; is that correct, sir?

A. Yes.

Q. Now, you mentioned that you can use either a mechanistic model or an empirical model to represent that process; that is, from the edge of the field to the gauging station; correct?

A. Yes.

Q. Have you done both?

A. Yes.

Q. You've done both as far as an analysis in watersheds; correct?

A. Yes.

Q. Okay. What is it about a mechanistic model that has the potential to increase error?

A. So the mechanistic model attempts to describe all the processes, or at least the more important processes, for phosphorus fate and transport between edge-of-field for a wastewater treatment discharge location and a watershed outlet or the gauging station.

Q. Are you aware of any mechanistic model that accounts for every single process in the stream for phosphorus?

A. No.

Q. Okay. So it tries to represent the most important processes; correct?

A. Correct.

Q. Okay. So what is it about that mechanism that has the potential to introduce error?

A. So not all watersheds are going to be same, and so some of these processes in the stream are going to differ from one location to another. A very good

example here in the Illinois River Watershed is the presence of springs, they're quite abundant, as well as opportunities for water to move underground and disappear even in locations and then reappear as a spring in locations further downstream.

So that would be an example of a process in the fate and transport of phosphorus from edge-of-field or wastewater-treatment plant discharge location to a gauging station or the watershed outlet that the majority of these mechanistic models would not represent well or would not represent at all. So that would present a real challenge in a location like the Illinois River Watershed to get that mechanistic model to work correctly.

Q. Okay. And what about some of the more traditional processes; where does the mechanistic model obtain the coefficients to represent those processes?

A. In most instances, there would potentially be coefficients that come with that model that have been derived from other locations. So they would represent relationships among some of these processes for a different location or a different group of locations and would not be specific to the watershed to which one would be applying that.

So it would be necessary to attempt, in most cases, to calibrate those coefficients to get them to reflect in some way the relationships among the various fate and transport processes for an in-stream model.

Q. Are you aware of any mechanistic model that is specifically applicable to the IRW?

A. No.

Q. Okay. Now, so you would have to then change coefficients for that model to try to match the IRW regardless; correct?

A. Correct.

Q. Now, if you -- do you calibrate mechanistic models?

A. You may and in some instances you may not, but you probably would in most cases.

Q. If you had employed a mechanistic model, would you have calibrated it in this watershed?

A. Yes.

Q. And what data would you use to calibrate it?

A. The same data that I used here. So I would have used the GLEAMS and wastewater treatment inputs into the stream and I would have used the observed data at each of the three gauging stations -- so the Illinois River at Tahlequah, the Barren Fork near

Eldon, and Caney Creek -- in order to obtain calibrated coefficients that went into the mechanistic model.

Q. If you had a completely descriptive or a mechanistic model and you used it in the IRW, would you expect to get the same results of P delivery from nonpoint sources in the IRW?

A. They may not --

MR. GEORGE: Objection, Your Honor; calls for speculation. I don't think that analysis is in the --

MR. PAGE: Your Honor, I believe this witness has sufficient expertise to offer that opinion.

MR. GEORGE: May I respond, Your Honor?

THE COURT: You may.

MR. GEORGE: With all due respect, one thing that's been demonstrated is the complexity of these models and different things that affect their outcome. The idea that this witness can testify as to the expected result of a model that has not been run on this watershed, I think, is a stretch.

MR. PAGE: May I respond, Your Honor?

THE COURT: Yes, sir. Go ahead.

MR. PAGE: This goes to the heart of

what the testimony that was offered by Dr. Bierman. He did not run a mechanistic model, yet he suggests that there's a problem with the modeling that Dr. Engel does. So he offered a similar type of opinion without running a model himself.

THE COURT: Well, but to speculate as to the results of such a model is different from criticizing because such a model has not been utilized. The objection's sustained.

Q. *(BY MR. PAGE)* Have you employed mechanistic models at other watersheds where you found you had difficulty because an error had been introduced?

A. Yes.

Q. Could you explain those circumstances -- would those circumstances be applicable to the IRW?

A. There would certainly be some -- some portions of those that would be.

Q. And what were the problems you found in those circumstances?

A. Well, the issues were the assumptions that were made about certain relationships among the various transport and fate mechanisms within those models, and therefore, the coefficients had to be adjusted. The coefficients were in some instances not

within expected ranges because those watershed conditions, those in-stream conditions, were different enough from the conditions under which the routing model had been developed such that one really had to calibrate some of the values into that model in a way that it would be outside the norm of it.

Q. Are you aware of any modelers that have tried to use a mechanistic in-stream model in the IRW?

A. Yes.

Q. Who is that?

A. Dr. Storm, in some of the work that he did, did use in-stream mechanistic models here in the IRW.

Q. And have you reviewed those results?

A. I have.

Q. And were there any issues related to Dr. Storm's use of a mechanistic model in the IRW?

MR. GEORGE: Objection, Your Honor; calls for hearsay. The witness is now being asked to testify as to work product of another expert and the conclusions and results from that expert's analysis.

THE COURT: Response.

MR. PAGE: Your Honor, it goes to the predicate for why he selected this model and its appropriateness. I'm not offering it for the truth of

the matter asserted but for the investigation that Dr. Engel employed to select the model.

MR. GEORGE: Your Honor, may I add that I don't believe this is proper rebuttal. It is not a disclosed topic. It's not refuting anything that Dr. Bierman said or testified to in this court. It's not been disclosed as a subject for this witness.

THE COURT: I think it's encompassed in the subject matter of mechanistic models versus this empirical equation. Overruled.

Go ahead.

Q. *(BY MR. PAGE)* Would you please explain, sir?

A. Yes. So Dr. Storm used the SWAT model in the Illinois River Watershed and within it a mechanistic routing model that's part of it and experienced very severe challenges with the routing of phosphorus here in the Illinois River Watershed. I would largely attribute that to the many springs, to the opportunities for water in this stream system to move into these fissures and cracks in the alluvium along these streams, and therefore, that routing model really didn't represent those processes.

Because they're far more important in the Illinois River Watershed than in many, many other

watersheds, there was a real problem in getting the routing model in that case to work and to match observed results no matter how much calibration and no matter the ranges of calibration coefficients employed.

Q. Did you actually consult with Dr. Storm concerning this issue?

A. I certainly had a number of conversations with him concerning this. And this was certainly --

MR. GEORGE: I'm sorry, Your Honor. The witness is about to testify to hearsay.

THE COURT: Sustained.

Q. *(BY MR. PAGE)* Did these conversations influence your selection of the model that you used in this case?

A. Yes, they did. So this caused me to reconsider the routing models to be used, and because of the available data, I chose to create an empirical routing model equation for the Illinois River Watershed versus opting for a mechanistic model.

Q. Now, does your empirical routing model account for phosphorus processes from runoff -- nonpoint-source runoff, edge-of-fields, to the gauging stations?

A. Yes.

Q. Would you explain that, sir?

A. Yes. So I guess -- let me clarify, though, that one can't unravel, uncouple some of these processes so those processes are all wrapped up together in the modeling coefficients.

So one can't ask the question, how much phosphorus is being uptaken by algae? One can't ask the question, how much phosphorus is being trapped with sediments that are temporarily detained?

So all of these things get combined in the empirical model into the set of coefficients and, so therefore, it does represent the processes, they're coupled together, but one can't readily uncouple those with the approach I used.

Q. Now, did you need to be able to uncouple those to answer the question as to whether or not nonpoint-source runoff, phosphorus, was reaching Lake Tenkiller?

A. No, it wasn't necessary.

Q. And was that the basis for you selecting the empirical routing model that you employed?

A. Yes.

Q. So if you know what's coming off the field from nonpoint sources, correct, from GLEAMS --

A. Right.

Q. -- and you know what's at the gauging stations --

A. Right.

Q. -- is that sufficient information to know how much nonpoint-source and point-source phosphorus is reaching the lake?

A. Yes, it would be.

Q. Does it also allow you to be able to predict what the impacts would be if nonpoint-source phosphorus discharges in GLEAMS changed?

A. Yes, it would.

Q. How so?

A. Well, the model would -- would account for those increases and the model equation would compute the increased amount of phosphorus -- assuming that the phosphorus increased in GLEAMS -- would compute the increased amount of phosphorus delivered to the stream gauging station and would do that on each day that inputs were provided.

MR. PAGE: May I have a minute, Your Honor?

THE COURT: Yes.

(Discussion held off the record)

MR. PAGE: Thank you, Your Honor.

Q. *(BY MR. PAGE)* Now, Dr. Engel, I want to

change topics with you. I would like you to please look with me, sir, to Demonstrative 428. I want to talk about Dr. Bierman's assertion that it was a mistake for you not calibrating your GLEAMS model to the edge-of-field data. It's Demonstrative 428 and testimony slide No. 9, sir. Do you have that?

A. Yes.

Q. "QUESTION: Now, Dr. Bierman, I remember you raising a concern that Dr. Engel did not calibrate the GLEAMS model to the edge-of-field using the hundred or so samples that he had for edge-of-field. Was that one of your concerns?

"ANSWER: My concern is that yes, he should have compared the output of his GLEAMS model to those data.

"QUESTION: Is it standard practice in the watershed community to calibrate to . . . edge-of-field?

"ANSWER: It's standard practice to use the data when they're available.

"QUESTION: I asked you a specific question, sir, with regard to the watershed modeling community.

"ANSWER: Well, it was standard practice apparently for Dr. Storm because he published a paper in 2007, sir, in which he -- he did three

site-specific studies in the Eucha-Spavinaw Watershed right here in Oklahoma where he specifically modeled and measured edge-of-field concentrations and compared his model output to those edge-of-field concentrations."

Now, Dr. Engel, are you familiar with this 2007 paper written by Dr. Storm?

A. I wouldn't characterize it is a paper. I've seen this, yes.

Q. Is it a peer-reviewed publication?

A. No. It's a report that was submitted to a state agency.

Q. And what was the purpose of this report?

A. The report was investigating the creation of a phosphorus index to be used on individual fields. And so Dr. Storm in the report investigated the creation of this phosphorus index, used Eucha-Spavinaw data, used other data, talked about the potential for calibrating the approach he was using in this phosphorus index, examined that but ultimately rejected the need to calibrate, did not calibrate, and presented results.

So, you know, again, just to make this clear, what he was creating was a field-level phosphorus index tool, not a watershed-level tool, and he didn't

calibrate at the end.

Q. So even though he was looking at a field-specific analysis, he still didn't calibrate this analysis using edge-of-field data?

A. Correct.

Q. Are you aware of a practice of calibrating watershed models without edge-of-field data?

A. No.

Q. Is that a typical or standard practice from your experience?

A. No. In the watershed modeling community, if one does calibrate -- and it wouldn't be necessary to calibrate watershed models in every instance -- but if one does calibrate, one would calibrate at the outlet of the watershed. So the scientific journals are full of papers where watershed modelers would calibrate at watershed outlets and validate at watershed outlets, not edge-of-field.

Q. And in the IRW, what are those watershed outlets?

A. So the watershed outlets that were of interest and met the needs for the analysis I was doing were the three we've been talking about, so on the Illinois River, the gauging station at Tahlequah, on the Barren Fork near Eldon, and on Caney Creek. So

there were gauging stations with ample observed flow and water quality data at those locations.

Q. And are those the locations for which you calibrated your watershed model?

A. Yes.

Q. Now, I want to change topics again with you, sir. Moving along here, I want you to look at with me, sir, if you would, Demonstrative 429, it's testimony slide No. 10, and it relates to Dr. Bierman's critique of your use of NCLD or national land cover database.

"QUESTION: If a modeler is using the National Land Cover Dataset, does the modeler have to make some interpretations of those codes?

"ANSWER: Yes. The codes don't correspond directly to the urban land, pastureland, forest, cropland. The user needs to determine first what are the characteristics of the site of the watershed for the particular site-specific application and then make judgments about how to use those codes to classify areas for the particular watershed model.

"QUESTION: Have you reviewed Dr. Engel's land use classification inputs to determine whether his judgments are accurate and realistic representations of the actual land uses?

"ANSWER: Yes."

"How did you conduct that . . . investigation?" Excuse me. "How did you conduct that review or investigation?"

"ANSWER: Aerial infrared imagery was overlaid with portions of Dr. Engel's land use classifications, and we noted a number of discrepancies in his classification of pastureland."

Now, do you agree with Dr. Bierman's characterization, Dr. Engel, that -- well, do you agree with his characterization of the interpretations that must be made by a watershed modeler such as yourself?

A. No.

Q. Why is that?

A. Let me explain the NLCD data.

So the NLCD data comes with predefined land use land cover classes. For the Illinois River Watershed, there were 15 such classes. And, in fact, one of those is labeled "pasture" so there was no need to interpret things to identify pasture.

Maybe expanding and using urban as an example, there were four classes that are -- that I put into the urban category. So those four classes were developed open space -- so a modifier to

developed being open space -- developed low intensity, developed medium intensity, and developed high intensity. So those were clearly the urban land use classes in this data set.

Q. So you classified all those as what in your model?

A. So the four urban ones I just talked about, the developed with these modifiers, I classified those as urban. Pasture was clearly identified, classified as pasture. Row crops was identified and left that as row crops.

Q. Okay. So is that the type of interpretation that you employed with this data set?

A. That was the type of interpretation that was needed, yes.

Q. Okay. Did you actually -- you reviewed Dr. Bierman's testimony. Did you actually go through and then look at specific aerial photographs to see if the NLCD data accurately characterized urban as urban or pasture as pasture?

A. No, I did not. That would not be standard practice. So watershed modelers widely use NLCD data for land use land cover data in their watershed models. In fact, as I recall, Dr. Bierman even concedes that that is the case. So this is the data

that's used for land use land cover in watershed models.

Q. Okay. So to make this clear, the errors that Dr. Bierman pointed out in his testimony and had several exhibits of aerial photos, are those mistakes that you made in interpretation of the NLCD data?

A. No.

Q. Where did those mistakes, if they are, in fact, mistakes, where did they originate?

A. So if those were mistakes, those would have been the identification of the land use class that USGS scientists perform. So they would have performed this analysis and would have made the interpretation as to which class particular locations went into.

Q. Can you think of any circumstance where a modeler, a watershed modeler, went behind the NLCD database and reinterpreted it for use in the watershed modeling project?

A. Not that I'm -- not that I'm familiar with.

Q. Okay. Now I want to switch topics with you again, sir. I want to discuss with you Dr. Bierman's claim that your values that you used for the urban areas in the GLEAMS model did not accurately represent phosphorus runoff from urban levels.

And if you would turn with me, sir, to

topic -- testimony slide No. 11 or Demonstrative 430. Are you with me, sir?

A. Yes.

Q. "QUESTION: Based on your review, did Dr. Engel model urban areas in a manner that's representative of urban areas?

"ANSWER: He didn't accurately represent the characteristics of urban areas, in my opinion.

"QUESTION: Can you explain the basis for that statement?

"ANSWER: Yes. The GLEAMS watershed model, for each land use type -- and the urban land use is one of the land use types used by Dr. Engel -- the GLEAMS model requires that the nutrient inputs be specified and that hydrology inputs be specified. Let's talk about the nutrient inputs first . . . ."

Now, Dr. Engel, you've read Dr. Bierman's testimony on this point; correct?

A. Yes.

Q. Do you agree with Dr. Bierman's characterization that your inputs were improper and did not represent nutrient runoffs of phosphorus for urban land uses?

A. No.

Q. Okay. Would you explain why you disagree,

sir?

A. Certainly. So the GLEAMS inputs use a number of descriptors to describe the land uses and nutrient management systems and other aspects of a location. So Dr. Bierman never ran the model with the inputs to see what impact there was. So it would be very, very difficult to simply look at a whole series of inputs because of the complex interactions and be able to say, well, this is what's going to happen. So there are many, many complex interactions in a model like this.

Further, the GLEAMS model uses a modified curve number approach --

Q. Okay. How did this issue affect Dr. Bierman's characterization of what you did?

A. Dr. Bierman characterized the model as being simply a curve number-based model when in reality there are significant interactions of this modified approach to look at soil moisture, and it accounts for soil moisture for movement of water through various layers in the soil. So looking at a single value would have been incorrect in this particular situation.

Q. Okay. Let me ask you just to explain for us laymen what a curve number-based model means.

A. In the simplest form, the curve number creates a relationship between land use or land cover, a single soil property, and then rainfall to describe expected runoff. Again, GLEAMS, though, uses a modified version of that and takes into account many, many additional inputs that are required in the model to understand and compute the expected runoff.

Q. Did Dr. Bierman account for these other potential input modifications when he critiqued your urban selections?

A. No.

Q. And so are there other mechanisms that are adjusted in GLEAMS to allow it to accurately reflect urban runoff?

A. Yes.

Q. And have you actually used GLEAMS before in your work, other than the IRW, to reflect urban runoff?

A. Yes. I've used that in several instances to do so.

Q. And did you find in those cases you had to adjust more than simply the curve number?

A. Yes.

Q. And did you make similar adjustments in this case?

A. Yes.

Q. Okay. What about the nutrient selection issue that Dr. Bierman mentions with regard to urban land use?

A. It would be a similar situation here, in that these complex interactions without running the model, it would be almost impossible to understand what's really happening. So the standard approach would be to run the model, see what happens, not to simply look at inputs and speculate what might be happening.

Q. Okay. I want to now change topics --

THE COURT: Before we do, let me ask this because I don't know the relative amount of the particular alleged misclassification is involved here, but a couple of times, I believe, the defense mentioned your characterizing of some of the urban spaces, alfalfa fields.

Any response?

THE WITNESS: Well, the urban areas would not have been totally characterized as alfalfa fields. So in the nutrient input files, it was necessary to describe something to make the model run, and the something that was used was alfalfa fields. Other parameters were then modified to represent what would be happening in urban areas but you still need a

descriptor in the model to do that.

THE COURT: I understand. I mean, you've got -- in an urban setting, you've got backyards, you've got driveways, you've got rooftops, you've got gardens, etcetera. Is that basically what you're talking about?

THE WITNESS: Yes. You've got a mosaic of uses.

THE COURT: Go ahead.

MR. PAGE: Thank you, Your Honor.

Q. *(BY MR. PAGE)* Dr. Engel, I want to change subjects again to move these things along. Part of Dr. Bierman's testimony was where he compared the amount of phosphorus -- the total amount of phosphorus in GLEAMS with your mass balance annual loadings. Do you recall that testimony?

A. Yes.

Q. Would you please look with me to Tyson Defendant Demonstrative 230?

MR. GEORGE: Your Honor, I would interpose an objection here. I don't believe this is a topic, mass balance, disclosed for rebuttal testimony for Dr. Engel. I'm looking at docket No. 2854, which was the filing that led to the hearing on January the 14th, and I don't see any reference to

mass balance.

THE COURT: Mr. Page.

MR. PAGE: Yeah. That document was filed with the court on the 13th. On the 12th, Your Honor, we had made a disclosure of exhibits we planned to use with Dr. Engel and this was one of the disclosures. So this document was clearly noticed on the 12th of January that we wished to use.

MR. GEORGE: Your Honor, maybe I misunderstood, but I understood the court's directive that led to the filing, which is cited in the opening paragraph of the filing, was to identify the topics. If I understand -- in fact, in the footnote, there was some reference of narrowing done by the state with respect to what their original plans may have been with regard to rebuttal topics. Frankly, the defendants have been operating off of this list as the contours of the filing -- I'm sorry -- of the state's rebuttal case and it's not on here.

THE COURT: The number of that filing again?

MR. GEORGE: It's docket No. 2854, filed on the 13th of January.

MR. PAGE: Your Honor, if I just may say, we also noticed other exhibits on Tuesday, which

we -- two others that we plan to use with Dr. Engel. So we've got a total of three exhibits that were used by the defendants that Dr. Engel related to.

One of those was noticed on the 12th and the other was noticed on the 19th, where in the course of the hearing, Your Honor, my impression was the court's ruling was that we would disclose any other additional documents.

So on the 19th, we informed the defendants that we're going to use what we've disclosed in this docket No. 2854 as well as the exhibits that were disclosed on the 12th and then the 19th.

THE COURT: All right. And I specifically recall the discussion about narrowing so Mr. George's conclusion would not have been unreasonable as between the 12th and the 13th that based upon the plaintiff's characterization that the planned rebuttal had been narrowed.

But you're saying that subsequent to the 13th, you identified on the 19th this as well as other exhibits that may go beyond the scope of the testimony identified in the filing of the 13th; is that correct?

MR. PAGE: Yes, Your Honor. I think that was on the 19th.

THE COURT: Was it filed?

MR. PAGE: No, sir. This was -- this was -- we followed the practice that was used for disclosures by mailing and providing either the demonstrative or the copy. And so on the 19th, we wrote to counsel that below are additional rebuttal demonstratives and exhibits for Dr. Engel -- I think the word "additional" is key -- which are disclosed, in addition to the materials provided by David Page on January 12th and then January 16th.

Of course, the 16th was the modeling results that you asked for, Your Honor, that we've already been through this morning.

THE COURT: Does this exhibit address any of the items set forth in 2854?

MR. PAGE: No, sir.

MR. GEORGE: Your Honor, you may have a copy of the document on your screen.

THE COURT: I do.

MR. GEORGE: Okay. Your Honor, may I make one observation -- one additional observation --

THE COURT: Yes.

MR. GEORGE: -- while the court is considering the document?

The court's ruling at the hearing on January the 13th was not a review of all the exhibits that had

been disclosed. Obviously, the court's ruling was based upon the filing that was made and the shape of the state's rebuttal case. There are numerous exhibits that have been disclosed by the state that will not be used with this witness.

I believe that the test appropriately for what the state has indicated its rebuttal case would be is the filing that we are going to use in front of Your Honor and Your Honor made rulings on. I don't believe there's been any reference to mass balance as a topic.

THE COURT: There is not. The objection's sustained. Mr. Page.

Q. *(BY MR. PAGE)* Okay. Dr. Engel, I'd like to now review with you Dr. Bierman's criticisms of your calculations of the observed loads at the three gauging stations in his testimony.

If you would look with me, sir, to Demonstrative 431, testimony slide 12. Do you have that, sir?

A. Yes.

Q. "QUESTION: Can you describe what you discovered when you reviewed the calculations by Dr. Engel to arrive at his observed phosphorus loads?

"ANSWER: Yes. Dr. Engel stated that he used

the USGS LOADEST program. And from review of his produced materials, I determined that he used LOADEST model 8. LOADEST has about 12 or 13 different models in it. And I reviewed his -- again, reviewed his model input files, and I determined that he made a large number of errors in taking the OWRB measurements and organizing them and formatting them for input to the LOADEST program. There were a large number of just flat-out mistakes, numbers were incorrect. There were a large number of OWRB data that were simply ignored."

Now, Dr. Engel, do you agree with those claims made by Dr. Bierman?

A. No.

Q. Would you please explain to me, sir, why you disagree with Dr. Bierman's claims?

A. So in getting ready to use the LOADEST program, there were a number of exploratory efforts that were undertaken. So initially the USGS concentration phosphorus data were obtained, there were runs made with that using different model versions. So as Dr. Bierman noted, there's some ten-plus model versions that LOADEST -- or forms of equations that LOADEST potentially can use.

Q. Now, let me just interrupt you here, if I

may, Doctor.
A. Sure.
Q. Did you produce all those exploratory runs as part of your considered materials?
A. Yes. There were certainly many exploratory runs that were produced as part of the considered materials. Later, I obtained OWRB data. That was ultimately used and combined with the USGS data. I explored the approaches that USGS had used in doing this. They used my recollection is model versions 3 and 6 in performing analyses here in the Illinois River Watershed.
So I ultimately decided to let LOADEST pick the model. I did explore model version 8. As I said, I explored other versions, but ultimately allowed LOADEST to select that model and use that. It looks like Dr. Bierman has used model 8.
I also noted that there were some additional data beyond the end of the data that I had that Dr. Bierman considered in some of the runs that he made in and the results that he produced. So there seems to be some confusion here in some of the early preliminary runs versus what was ultimately used.
Q. Did USGS, when it calculated loads at these gauging stations, always use LOADEST model 8 that

Dr. Bierman used?

A. No. So they used different model versions, and my recollection is model 3 in one case, model 6 in another case.

Q. And how does your modeling of these gauge station loads compare to what USGS did?

A. There were some comparison with the predicted loads with what USGS did. The approach is similar to what USGS used. Where they used different models, model versions, I used different model versions.

Q. So when Dr. Bierman concluded that you used -- you made mistakes in the modeling, did he use the same LOADEST model that you did?

A. He seems to have used LOADEST model version 8.

Q. And did he use the same data that you did?

A. I did note that there were some additional data beyond the period, and I believe prior to the period that I started, that were also entered in his input files.

Q. And this is based on your review of his considered materials?

A. Correct.

Q. Now, Dr. Bierman was critical not just of your total phosphorus observed calculations, but he

was also critical of your SRP, or soluble-reactive phosphorus, also; correct?

A. Correct.

Q. Do you agree with Dr. Bierman's analysis of your SRP calculations?

A. No. I believe, again, it's the same situation. There were various model versions data that were explored so there were soluble as well as soluble-reactive phosphorus data that were explored.

Q. Okay. Now, Dr. Engel, I want to switch witnesses on you now. I want to go from Dr. Bierman to Dr. Connolly.

Now, sir, did you review the testimony of Dr. Connolly in preparation of your rebuttal testimony today?

A. Yes.

Q. Okay. Now, what I want to focus on with Dr. Connolly is Dr. Connolly's opinion and testimony that wastewater-treatment plant phosphorus is a phosphorus that's having the dominant impact on the IRW, all right, sir?

So I would like to turn with you first to Demonstrative 432. Do you have that, sir?

A. Yes.

Q. "The Court: Now, you say 'a dominant

impact.' Are you saying the dominant impact or one of the dominant impacts?"

"The Witness: Based on the data that I have, it appears to be the dominant impact"?

"QUESTION: And what form of phosphorus are they seeing that 80 percent of the time?

"ANSWER: It's dominantly dissolved phosphorus, as we saw earlier in the plot of how much of the phosphorus is dissolved versus river flow. Under base flow conditions, it's probably on (the) average of 80 to 85 percent dissolved, and from the wastewater-treatment plants being the source, most of that dissolved is soluble-reactive phosphorus.

"ANSWER: And that correspondence confirms for me the dominant source of . . . wastewater-treatment plants under base flow conditions that are occurring eight out of ten days during the principle growing period for algae further reinforces the idea that the wastewater-treatment plants are providing the phosphorus to the algae, and then lastly, the idea that most of that phosphorus is in a form that algae can use."

Now, Dr. Engel, do you agree with Dr. Connolly's opinions concerning the dominant form of phosphorus in this watershed being from

wastewater-treatment plants?

A. No.

Q. Why is that?

A. I conducted an analysis of the data from the watersheds that were used in the poultry house density analysis -- the court may remember my testimony on that earlier, I guess last year now at this point -- in which we looked at runoff, as well as base flow, from 12 subwatersheds in the Illinois River Watershed. The 12 that were used in my analysis did not have wastewater treatment impacts in them so there were no wastewater treatment discharges in these 12 watersheds.

The base flow data, we had both total phosphorus as well as soluble-reactive phosphorus available from those watersheds. My analysis of that data clearly indicates there's soluble-reactive phosphorus in base flow coming from these watersheds, and it ranges from, I believe, seven to about sixty, eighty, ninety micrograms per liter, and it represents about two-thirds of the total phosphorus -- soluble-reactive represents about two-thirds of the total phosphorus in base flow from these watersheds.

So clearly there are other places, other nonpoint sources, contributing soluble-reactive

phosphorus to base flow.

Q. Now, Dr. Engel, would you look with me on Demonstrative 414, please? What is this, sir?

A. So this table summarizes the soluble-reactive phosphorus data from these small watersheds or small tributaries that I was describing a moment ago.

So each of those 12 watersheds is labeled here under the watershed, this first column, so HFS 02 is the first of these. And then at the bottom, some averages are going to be presented.

The second column represents the average base flow soluble-reactive phosphorus in micrograms per liter. That ranges from a low of 7 for high flow station 26 to 51, it looks like, for high flow station 16 and the average is 27.

Q. So that's all soluble-reactive phosphorus that's concentrations displayed there?

A. Correct. So these would be soluble-reactive phosphorus in base flow from multiple samples from these locations.

Q. Did all of the subwatersheds that you analyzed that did not have wastewater-treatment plant discharge have soluble-reactive phosphorus in base flows?

A. Yes.

Q. Okay. And what was the -- what's the third column, sir?

A. So the third column just depicts the amount of soluble-reactive phosphorus as a percentage of the total phosphorus in base flow again from these 12 watersheds. So you can see that ranges from about 30 percent to 96 percent for HFS 28A being at 96 percent, and on average presented at the bottom about two-thirds of the phosphorus in base flow from these small watersheds is soluble-reactive phosphorus.

Q. Now, sir, how is it that nonpoint-source phosphorus, which is by definition runoff phosphorus, can contribute phosphorus and even soluble-reactive phosphorus to base flows?

A. Well, this could occur in via one of two primary mechanisms.

So, first of all, there would be -- as we would have rainfall, there would be some amount of water that infiltrates, moves through this soil and on its path through the soil would pick up some phosphorus. That might become groundwater, shallow groundwater, that's later discharged during dry days into these streams and rivers. So that's going to be seeping out of the banks and re-entering the stream beds of some of these.

The second way would be that during runoff that runoff may be moving through the streams. It would be carrying some amount of phosphorus with it. But during that process, some of that runoff would refill the voids that are left by -- by the -- by the water seeping back into the streams. So during the surface runoff, water pushing out, filling the alluvium along the streams, and then on dry days, that water carrying phosphorus moving back in and trickling and moving slowly in these streams representing base flow.

Q. So is it your testimony, sir, that the alluvium of these rivers and streams when the river or stream drops will contribute nonpoint-source phosphorus to these streams?

A. Yes. There would be nonpoint-source phosphorus coming back out of the alluvium, reaching the streams, and then flowing slowly to downstream locations.

Q. And that would be during base flow conditions, sir?

A. That would occur during base flow conditions.

Q. Okay. Now, does this evidence indicate or support Dr. Connolly's opinion that wastewater-treatment plant discharges are the dominant

form of SRP during base flows in the IRW?

A. Well, you know, there are many, many of these small streams, and based on the data here, certainly have soluble-reactive phosphorus in them at base flow. So based on this analysis, it's quite clear that there are nonpoint sources of phosphorus in base flow so there's no more phosphorus than just wastewater-treatment plant at these lower flow conditions.

Q. And that would include soluble-reactive phosphorus from nonpoint sources also?

A. Certainly would include soluble-reactive phosphorus.

Q. Now, did you make a comparison of these soluble-reactive phosphorus results to poultry house density?

A. I did.

Q. And what did you find?

A. Well, similar to the analysis when I looked at just total phosphorus coming from these watersheds, I found significant relationships. So let me explain what I did.

So I looked at, in this case only, soluble-reactive phosphorus, I looked at poultry house density in these 12 watersheds, and then looked at

that relationship, created a regression line among those looking at poultry houses, as I did for total phosphorus in the watershed, both active and total, looked at a buffer around the watershed because poultry house operations, nearby watersheds would potentially contribute phosphorus into these watersheds by transport of the waste application then of that waste in that watershed. So that two-mile buffer was used. And, again, regression lines fit to each of these.

For each case, you get a relationship that as you have more poultry houses, you have more soluble-reactive phosphorus in base flow and each of these were statistically significant at a P value of .05

Q. Did you reach any conclusions based on this analysis?

A. Yes. Based on this analysis, it's quite clear that poultry house operations in these watersheds contribute soluble-reactive phosphorus in base flow, and the other prior analysis indicates they contribute certainly during runoff events as well.

Q. Now, one of the premises for Dr. Connolly's opinion that wastewater-treatment plant phosphorus is the dominant -- that is, is dominant in the Illinois

River is that the Illinois River is moving too fast to utilize nonpoint-source phosphorus.

Do you recall that testimony?

A. Yes.

Q. Now, do you agree with that?

A. No. And, I guess, for a couple of reasons, if I could explain those.

So, I guess, first, the analysis that he did was flawed in that he looked at average conditions. In looking at flow velocities and the amount of time that it would take water to move downstream, looking at an average is probably not a preferred way to do that.

So, for example, if you simply look at the median, which would represent conditions half of the time, the travel time and velocities change by 40 percent. So --

Q. Forty percent faster or slower?

A. So velocities would be 40 percent slower, travel times would be 40 percent bigger. So the time and days would be bigger, the speed would be smaller.

So that would represent the conditions half the time. Certainly, there are many, many days -- half the days would be conditions in which velocities would be slower than that, travel times would be

greater than that. And so if we get out here in the 25-percent-of-the-time range, very, very different than the characterization of Dr. Connolly.

I guess I would further note that, you know, there's a little bit of a flaw in that logic too in that, you know, as the water is moving past a location, it's carrying phosphorus. Well, the water behind that is also going to be carrying phosphorus. And based on the analysis that I just talked about, with soluble-reactive phosphorus being in base flow in these small watersheds, that's nonpoint-source phosphorus that's right behind this other phosphorus.

So the travel time doesn't really tell the story with respect to potential exposure of algae to phosphorus.

Q. Is that because the phosphorus may move down in three days or two days or even a day, but there will be phosphorus based on your analysis right behind that phosphorus that moved by?

MR. GEORGE: Objection; leading.

THE COURT: Sustained.

Q. *(BY MR. PAGE)* Why is the daily analysis not probative to the amount of phosphorus that's actually seen or for which algae's exposed to in the IRW system?

A. So the algae is going to see phosphorus every day from water flowing past it. And, again, as I explained, even in these lowest flow kinds of conditions in base flow, there's soluble-reactive phosphorus and other phosphorus that one can readily attribute to poultry house operations.

Q. Is it reasonable in your mind, Dr. Engel, to use the Illinois River main stem to characterize what would be typical flow in the IRW stream system?

A. Well, if one thinks about the many, many stream miles that are in much smaller streams and looks at the flow in those, the flow in those is certainly much less than the main stem. Velocities in those are on average -- or if we look at a median or quartile, you know, 25 percent of the time, the velocities, the exposure to phosphorus in those, ample opportunity for algae to see plenty of phosphorus.

Q. Okay. Now, Dr. Engel, I want to show you one of the exhibits that Dr. Connolly used to support his opinion that wastewater-treatment plant is the dominant form -- source of phosphorus for the IRW.

Would you please look at DJX6097? Now, did you review Dr. Connolly's testimony associated with this exhibit?

A. Yes.

Q. And what was -- if you could briefly summarize, what was Dr. Connolly's point that he made with regard to this exhibit and the dominance of wastewater-treatment plant phosphorus in the system?

A. So Dr. Connolly's argument was that if we look in these figures, we see this blue bar that represents the wastewater treatment discharge on a typical day. The other bars here represent some number of observations of phosphorus loads during base flow kinds of conditions for this period.

And his argument was that if you look at these, the wastewater treatment matches the observed phosphorus for this period of record.

Q. Okay. Were you able to evaluate using Dr. Connolly's evidence and his data whether or not the phosphorus in base flow is 80, 85 percent, all wastewater-treatment plant phosphorus?

A. Well, if we look at this bottom figure for Tahlequah, so the bottom figure on the page, the phosphorus load at Tahlequah is about 94 kilograms per day as I recall.

Q. Did you do some calculations based on this data to determine that?

A. Yes. And then I can use the boxes here -- or the bars here to calculate the phosphorus load that

would be the average phosphorus load depicted by the bars. So the bars represent a proportion of time in which a certain load was observed.

So if we look at the bar on the left, total phosphorus, with a -- with a mark in here of ten and we see that that represents about five or six percent of the time, multiplying five or six percent of the time -- and you can see the data to do this -- along with the average load represented by that box, do that for all these, sum these up, you can get the total load of phosphorus that's depicted by the observed data.

Q. And what is the total load of phosphorus during base flow at Tahlequah using Dr. Connolly's data?

A. Turns out it's about 156 kilograms per day, and that is to be compared to wastewater treatment at 94 kilograms per day. So that would mean that about 40 percent at least of the observed loads would be not wastewater treatment, they would have to be nonpoint source.

Q. Forty percent of the phosphorus would be nonpoint-source phosphorus at Tahlequah during base flow?

A. That's what these data would indicate.

Q. Now, again, sir, is it reasonable in your mind for Dr. Connolly to use just the main stem of the Illinois River to characterize the phosphorus contributions for all the streams in the IRW?

A. No. There are many, many stream miles in these small streams that have no wastewater treatment in them. Again, based on the review of the data that I conducted, there's clearly soluble-reactive phosphorus being contributed by those streams during low flow or base flow kinds of conditions.

MR. PAGE: May I have a minute, Your Honor?

THE COURT: Yes, sir.

(Discussion held off the record)

MR. PAGE: Your Honor, I pass the witness.

THE COURT: Cross-examination.

MR. GEORGE: Your Honor, if you'll give me a moment to relocate, it will take me a few minutes to get some materials set up.

I do note it's a quarter 'til and I'm at the court's pleasure as always as to whether to start for a few moments or to take a lunch break earlier.

THE COURT: Let's take it until noon when we're at a convenient break about that time.

MR. GEORGE: I appreciate that, Your Honor.

THE COURT: Yes, sir.

(Discussion held off the record)

CROSS-EXAMINATION

BY MR. GEORGE:

Q. Good morning, Dr. Engel. Welcome back to Tulsa.

A. Thank you.

Q. Good to see you again. Dr. Engel, I want to start with the one time -- and I think there was only one -- when Mr. Page asked you if Dr. Bierman lied or was untruthful.

Do you recall the question when Mr. Page asked whether you agree with Dr. Bierman's testimony that the routing model as described on page D-21 of your report had numeric values assigned to that model? Do you recall that question?

A. Yes.

Q. Okay. Let's get this straight, if we can. Do you have your report with you?

A. I believe there's a copy here.

Q. Okay.

MR. GEORGE: Your Honor, do you have a copy?

THE COURT: I do.

MR. GEORGE: Okay.

Q. *(BY MR. GEORGE)* Could you find page D-21, Doctor?

A. Okay.

Q. And do you see your routing model? In fact, the very first sentence at the top of page 21 begins with the phrase "a phosphorus routing model was created." Do you see that phrase?

A. Yes.

Q. And then the routing model is actually described on that page, the formula for that routing model; correct?

A. Correct.

Q. Okay. So you don't -- you're not of the view that Dr. Bierman was being untruthful when he said your routing model is described on page D-21 and that routing model does provide for coefficients in his formula but does not specify numeric criteria? You don't disagree with that, do you?

A. Well, I guess the numeric values are specified a page later.

Q. Okay. Well, let's turn to that page, page D-22.

The numeric values that you're referring to

are the coefficients listed in table 7; is that correct?

A. Correct.

Q. Okay. And there are, in fact, numeric criteria beneath each of those coefficients for each of the subwatersheds; right?

A. Yes.

Q. Do you see directly above the table how those coefficients are described? Do you see the sentence that the optimized coefficients are shown in table 7?

A. Yes, I do.

Q. Okay. And that's a fair description of what table 7 shows, right, optimized?

A. Yes.

Q. Okay. And then if you go back up one -- the last sentence in the first full paragraph on page D-21, do you see the sentence that provides "the routing model coefficients were optimized using an automated shuffled complex evolution approach"? Do you see that sentence?

A. Yes.

Q. The shuffled complex evolution that is referenced there is this SCE algorithm that has been discussed a time or two in this case; is that right?

A. Correct.
Q. And that's part of your calibration process, right, the use of the SCE?
A. Right.
Q. So is it not true, Doctor, that the coefficients that are shown in table 7 that do have numeric values assigned to them are the product of your calibration using the SCE algorithm?
A. Yes.
Q. Okay. So those specific numeric values for your coefficients came into being, if you will, as a result of the calibration process; correct?
A. Yes.
Q. And I believe you testified on your previous time in this court that the calibration process with this SCE involves moving coefficients and parameters up and down in order to reach the best fit in terms of predicted loads versus observed loads; correct?
A. Correct.
Q. Okay.
MR. GEORGE: Can we pull up as well State Demonstrative 392?
Q. *(BY MR. GEORGE)* You're familiar with this demonstrative exhibit, are you not, Doctor?
A. Yes.

Q. Do you see it on the screen? And this is a demonstrative that you prepared, is it not?

A. Yes.

Q. And for the record, could you read the title of the demonstrative?

A. Yes. "Dr. Engel's Routing Model."

Q. Okay. And the equation with the generic coefficients of A, B, C, and P accumulation is what is shown on that demonstrative; is that right?

A. Yes.

Q. Okay. So, Doctor, when you describe that equation with the coefficients without specific numeric values as your routing model, were you just being careless?

A. I guess I'm unclear as to what you're asking now.

Q. Well, I believe your testimony on direct today has been that your model is not the equation, your model is the equation with these specific numeric coefficients plugged into it; correct?

A. Yes.

Q. Okay. But that's not what's represented on State Demonstrative 392, is it?

A. I guess they're placeholders for those specific numerical values in this -- in this

demonstrative, yes.

Q. Okay. So I guess I want to get some clarity on this so as we move forward we don't miscommunicate.

You don't have any objection, do you, to our referring to the routing model as the equation without the specific numeric coefficients, just as you've done on State Demonstrative 392?

A. That would be fine with me.

MR. GEORGE: Your Honor, the next subject I want to explore will take a little while to get into. Before we reach a logical place, would now be as good a time as any?

THE COURT: All right. Let's take our lunch break at this time. We'll be back at ten after one.

(Lunch recess was taken)

C E R T I F I C A T E

I, Brian P. Neil, a Certified Court Reporter for the Eastern District of Oklahoma, do hereby certify that the foregoing is a true and accurate transcription of my stenographic notes and is a true record of the proceedings held in above-captioned case.

I further certify that I am not employed by or related to any party to this action by blood or marriage and that I am in no way interested in the outcome of this matter.

In witness whereof, I have hereunto set my hand this 25th day of January 2010.

s/ Brian P. Neil

Brian P. Neil, CSR-RPR, CRR, RMR
United States Court Reporter